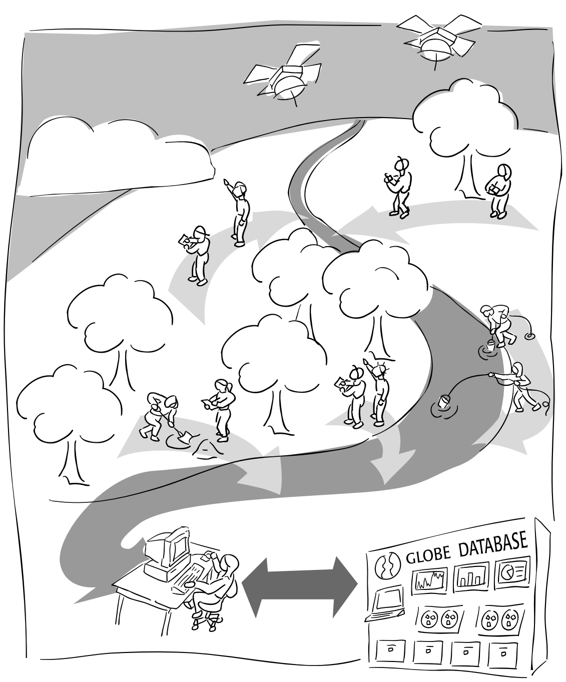
Introduction

The Big Picture

GLOBE student observations of the atmosphere, surface water, soil moisture and temperature, and vegetation all are impacted by seasonal changes as Earth orbits the Sun. These seasonal changes illustrate the interconnectedness among these aspects of our environment. Many important seasonal phenomena and regional differences can be studied based on the environmental and climatic parameters measured in the GLOBE program. Seasonal change is a response to increasing or decreasing levels of solar energy input, and GLOBE measurements are windows into these changing energy levels.

The Seasons investigation integrates science concepts and data from the various protocols. Your students will explore annual planetary changes – seasons – as a focal point for integrative learning. This chapter has two major areas of emphasis:

1. Learning science content – Helping students learn about seasonal cycles and helping them explore the interconnectedness among all aspects of the Earth system



2. Developing investigation skills – Helping students learn how to design and conduct their own GLOBE investigations

The concept of seasons is simple enough for students of all ages to grasp, and yet, it can be investigated at many levels. For K-3 students, the goal of the Seasons chapter is to observe many of the changes that occur throughout the year and to understand their observations and measurements as windows into large-scale, complex changes. For intermediate and advanced students, an additional goal is to understand the factors that underlie the differences in seasonal patterns around the world.

Why Are There Seasons?

Like tides washing regularly across a beach, seasons advance and retreat across the face of the globe and bring changes that transform the face of the Earth. Whether it is the arrival of the winter snows, the monsoon rains, or the summer heat, our environment changes constantly, and these profound changes occur over relatively short time periods. What helps make such huge, complex changes comprehensible is that they reoccur in predictable ways. Many ancient civilizations observed that the Sun's position in the sky changed throughout the year and were able to construct calendars and predict seasonal change based on their observations.

All seasonal changes are driven by changes in the amount of the Sun's energy reaching the Earth's surface (i.e., the amount of *insolation*). For example, more energy leads to higher temperatures which results in more evaporation which produces more rain which starts plants growing. This sequence describes Spring at mid-latitudes. Since visible light is the main form of solar energy reaching Earth, day length is a reasonably accurate way to gauge the level of insolation and has long been used as a way to understand when one season stops and the next one starts. For example, the first day of summer (the *summer solstice*) is the longest day of the year. Winter starts on the shortest day of the year, the *winter solstice*. The first days of fall and spring are when the day and night are of equal length – roughly 12 hours each. These days are named the *vernal* and *autumnal equinoxes*.

Changing day length implies that the Earth's axis of rotation is inclined with respect to the plane of its orbit around the sun. The ancient Greeks knew that the Earth was inclined 23.5°. Figure SE-I-1 shows the inclined Earth at different positions in its orbit. Notice how at the solstice positions, each pole is tilted either toward or away from the Sun. The pole inclined toward the Sun receives 24 hours of sunlight, and the one inclined away is in the Earth's shadow and experiences 24 hours of darkness. At the equinox positions, the Earth is inclined in a way so that each pole receives equal amounts of insolation. This discussion focuses on the poles because they experience the greatest extremes of insolation. Because of the inclination of the Earth's axis, insolation levels at every point on Earth change constantly. We call the effects of these changing levels seasons.

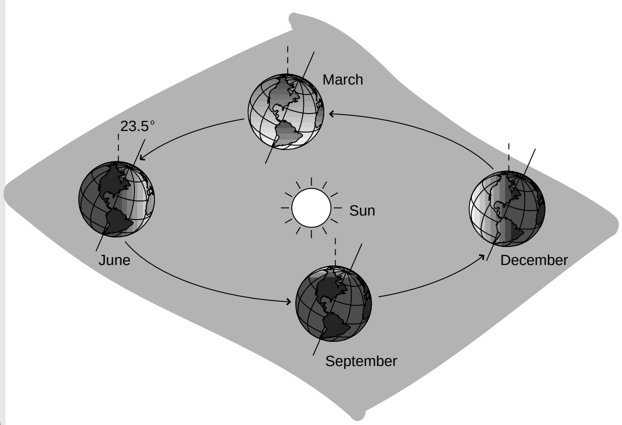


Figure SE-I-1: Positions of Earth in relation to the sun on the solstices and equinoxes

Latitude

Figure SE-I-2 shows how insolation levels vary with latitude. Because of this variation, latitude has a powerful influence in determining seasonal conditions and the annual patterns of environmental and climatic parameters such as precipitation and temperature.

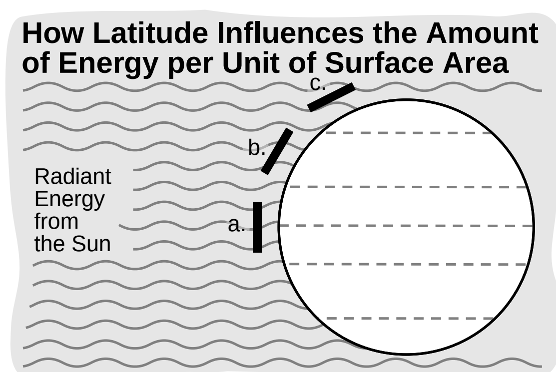
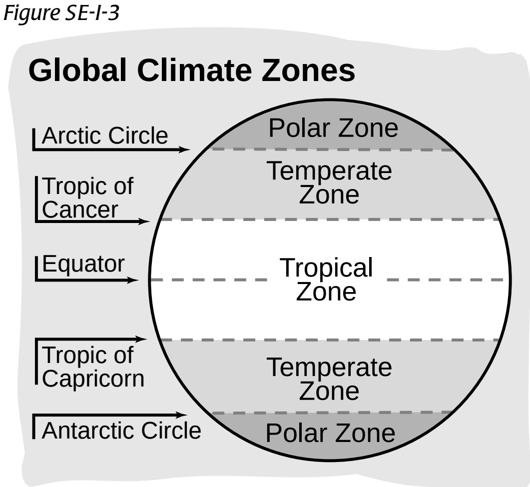


Figure SE-I-2: Areas a, b, and c are all the same size, yet they all receive different amounts of the sun's "rays."

Different Climatic Zones

The same season can be quite different in the *Tropical*, *Temperate* and *Polar* zones. These seasonal differences are based on the duration and directness of insolation. See Figures SE-I-2 and SE-I-3.

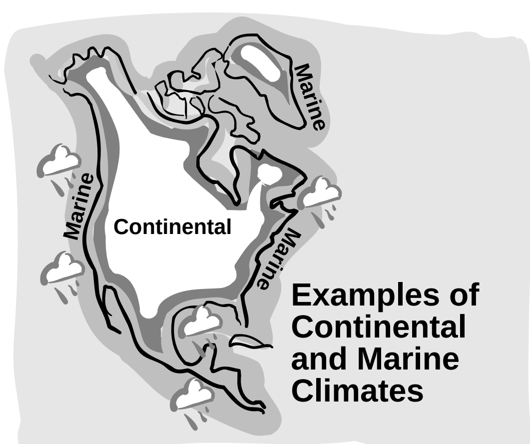
Figure SE-I-3



Continental and Marine Climates

Marine climates have larger amounts of moisture and smaller temperature changes from summer to winter than continental climates. However, the size of a continent affects both the temperature range and the amount of moisture in the interior – the larger the continent, the larger the effect. See Figure SE-I-4.

Figure SE-I-4

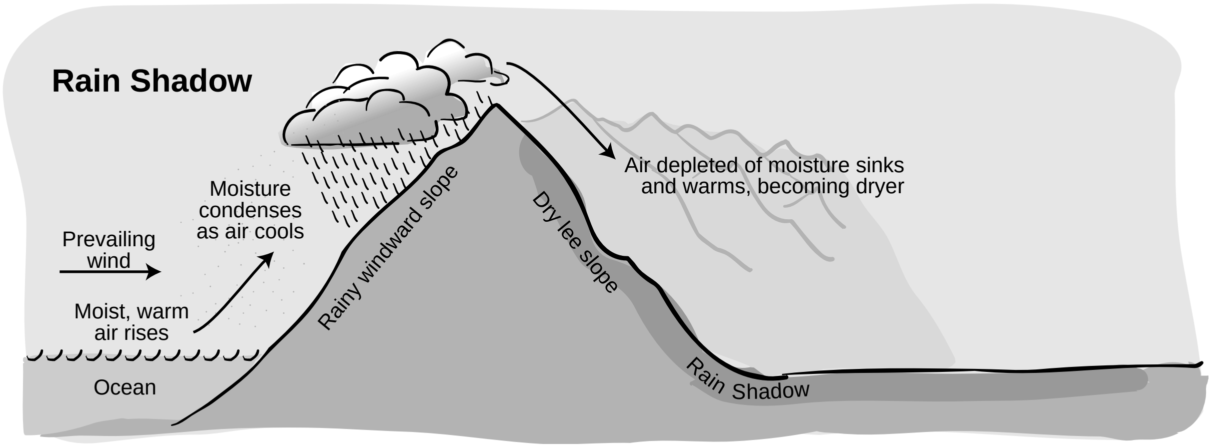


Two Key Factors That Affect Precipitation Levels

Amount of Water Vapor: Evaporation is how most of the water vapor enters the atmosphere, and air near large bodies of water such as oceans have the highest levels of water vapor. Also, higher temperatures increase evaporation rates. Consequently, air in tropical regions downwind from large sources of water tends to have the highest levels of water vapor, while air in temperate and polar regions in the center of large continents tends to have the driest air. In this example, *geography* influences amount of water vapor that influences precipitation levels.

Temperature: Though evaporation increases as temperatures rise, warm air holds more moisture than cool air. Warm air can cool in several ways. On a local level, the atmosphere cools at night, and the morning dew is the result of the water vapor condensing on cool surfaces. Warm air masses can move to cooler locations. Many storms start as warm, humid air masses that move to higher, cooler altitudes and latitudes. In this example, *latitude* influences temperatures which influence precipitation levels. Finally, increases in elevation cause air to cool. Generally, the atmosphere cools 1°C for every 150 meter rise in elevation. A considerable percentage of the water vapor in air rising over mountains condenses and falls as precipitation. In this example, *elevation* and *geography* influence temperatures which influence precipitation levels.

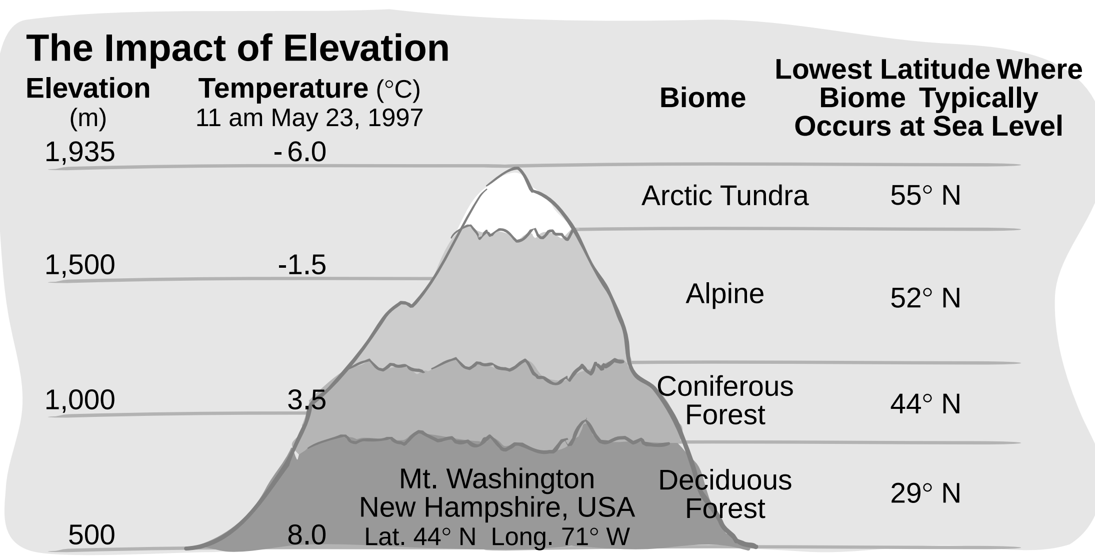
Figure SE-I-5



Geographical Features

Geographical features have profound impacts on nearby regions. For example, mountain chains can cause moist air to rise and precipitate out almost all of its moisture. When this *desiccated* (depleted of moisture) air descends to the regions behind the mountain chain, it creates a *rain shadow*. See Figure SE-I-5. Many deserts are found in such rain shadows. In addition to arid land, typical desert regions lack the atmospheric moisture that acts as insulation between the Earth's surface and space (water is the major greenhouse gas on Earth). Consequently, desert areas easily radiate their heat energy out to space, and day and night temperature differences are considerable.

Figure SE-I-6: A comparison of elevation, temperature, biome and latitude on Mt. Washington



Elevation

Changes in elevation can affect the environment as much as changes in latitude. Temperature falls approximately 1°C for every 150 meter increase in elevation, and, in terms of growing season, every 300 m increase in elevation is roughly equivalent to moving toward the nearest pole by 400-500 km (roughly four to five degrees of latitude). Mountain tops can be thought of as climatic islands where, in the Northern Hemisphere, northern species extend their ranges southward onto mountains where conditions resemble those of more northern latitudes. Plants growing on the top of New Hampshire's Mt. Washington (1,935 m) would feel right at home growing at sea level in the Arctic tundra, 2,400 km to the north in Canada. See Figure SE-I-6.

Global Energy Transfer Systems

As illustrated in Figure SE-I-2, the tropics receive more energy from the sun per unit of surface area than temperate or polar zones. In fact, even though the warmer tropics radiate more heat to space than high latitude regions, the tropics receive more energy from the sun than they radiate away! Where does this excess energy go? The circulation of the atmosphere and the oceans carries this energy, in the form of heat, to higher latitudes. See Figure SE-I-7.

If we consider the average north-south motion of the atmosphere, warm air from near the equator rises and moves toward the poles. At roughly 30° latitude, the air cools, falls and moves equatorward near the surface. A similar pattern exists in the polar zones, with air rising at roughly 60° latitude and falling at the poles. Since the tropical and polar zones bracket the temperate zones, the tropical and polar circulations drive the circulation patterns of the temperate zones. As a result, the air in temperate zones moves poleward at low altitudes, rises at roughly 60°, returns equatorward aloft and falls at roughly 30°.

In the oceans, strong currents such as the Gulf Stream, the Brazil, the East Australia, and the Kuroshio carry warm water from the tropics to latitudes of roughly 50°. Less prominent currents also contribute to this heat transport. Consequently, regions at high latitudes adjacent to an ocean, such as Ireland, have climates typically associated with regions at lower latitudes.

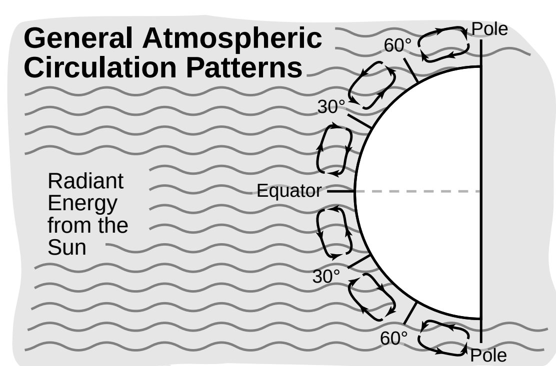
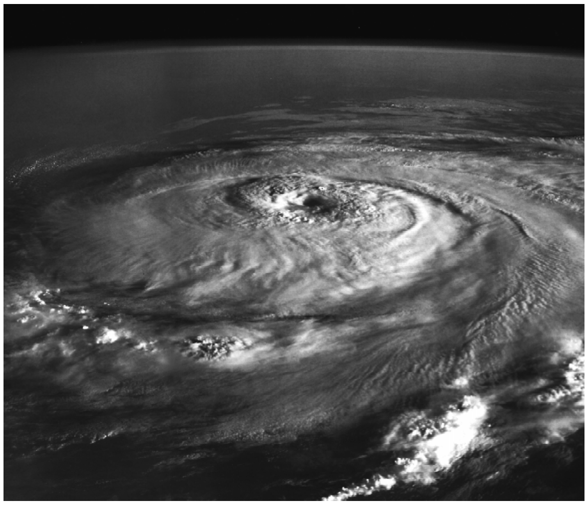


Figure SE-I-7: The rising of heated air and the sinking of cooled air drives atmospheric convection cells.



How Are Components of the Earth System Impacted by Seasonal Changes?

The atmosphere is perhaps the most obvious in its seasonal changes. There are annual cycles in temperature and precipitation. Hurricanes and tropical storms are season-dependent, as are droughts and monsoons. Storm systems result from large-scale movements of air masses that are strongly affected by seasonal changes.

Earth's ecology has adapted to Earth's seasonal changes in some remarkable ways. Animals migrate during the year to avoid extreme conditions. Most species have annual reproductive cycles. Plants have their highest photosynthesis levels in the summer when the sun is highest, and then some drop their leaves so that they do not drain their energy resources during the winter. Seeds germinate when soil temperature and moisture are favorable.

Soil conditions vary seasonally. For example, seasonal biological changes such as leaves falling enrich the soil. Soil conditions also vary seasonally as a result of changes in precipitation patterns, and your students might find differences in the rate at which rain soaks into the ground at different seasons.

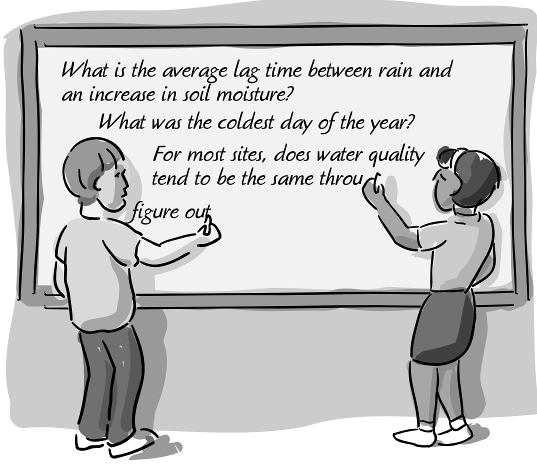
The hydrologic cycle shows seasonal changes in all aspects of the water cycle. Rainy and dry seasons affect the quantity and quality of water in rivers and lakes. Catastrophic flooding can occur in spring as winter snows melt. Seasonal monsoons are essential for the replenishment of water reserves in many parts of the world.

Students' Own Investigations Teach Research Skills

This chapter is a set of integrated student activities. Within the broad domain of seasons, students ask questions, speculate about ideas, observe their study sites, collect and analyze data, communicate with other students and scientists, use multiple sources of information, and communicate their findings.

By doing such investigations, students learn how to do scientific research. In addition, this hands-on, inquiry-based approach is also a powerful way for students to learn science content. By designing and implementing their own investigations, students engage in multidimensional learning that is far more effective than reading science in textbooks.

In these activities we emphasize the analysis of local as well as global data. The best investigations emerge from the questions that the students themselves ask as they observe their study sites and explore the GLOBE database. Be alert for questions that can serve as springboards for investigations. As questions come up, have students record them in their GLOBE Science Notebooks.



An Overview of Student Assessment in the Seasons Investigation

Since student investigations are a major focus of the Seasons Investigation, your evaluation should emphasize assessing the quality of their investigations. While specific assessment questions are listed at the end of each activity, we suggest that you evaluate your students' progress at three stages of their investigations:

1. In the early stages, what kinds of questions are they asking?
Your students should demonstrate a questioning attitude as they observe their study site and look at the GLOBE data. Their questions should show genuine personal curiosity and be based on a novice's understanding of the science domain. As the students select questions for further investigation, they should have a reasonable chance of finding answers with further observations of the study site or deeper analysis of GLOBE data.

2. In the middle stages, are they able to make sense of the data?
This stage emphasizes the use of study site observations and GLOBE data. For younger students, do they observe carefully, record their observations accurately and find patterns in their observations? For older students, do they understand the measurements on which the GLOBE data are based, are they able to use graphs and maps to analyze the data, and do their analyses make sense?

3. In the later stages, are they able to communicate findings to others?
When they complete their investigations, students need to be able to share their findings with you, their classmates, GLOBE scientists, and students throughout the world, and the general public. Whether their communications are in written or verbal form, do the students demonstrate a clear understanding of their investigations? Do they understand the underlying systems they are investigating and the relationships within such systems? Are they able to communicate clearly to their audience? Does the investigation itself show the depth and quality that you expect from a student at this level?

We also encourage you to assess students' understanding of content and interconnections. Students could, for example, construct concept maps (if this is a device you use) or reports or displays that explain the systems and causal connections that they've been investigating.

Implementation Recommendations

1. Do at least one learning activity from another protocol.
The Seasons Investigation is best implemented after your students have begun exploring their study sites and begun collecting and submitting data for at least one of the protocols. It is even better if you have data from additional protocols, either from your own class or from other collaborating classes in your school or district.

2. Accumulate data over the full year.
Exploring seasonal changes requires having enough data for your students to begin to identify changes over the course of the full year. This underscores the importance of beginning your measurements early in the year and doing them regularly, as detailed in the protocols. If your school has been in GLOBE less than one year, you can use data from a nearby school or from several weather data bases available in the GLOBE Resource Room. Some of these data bases have data from thousands of stations going back several hundred years, in some cases.

3. Promote a questioning attitude all the time.
With GLOBE investigations, and in real science research, an important skill is the ability to ask interesting questions. You can make questioning a more important part of your classroom by encouraging students to record their questions in their GLOBE Science Notebooks and by reviewing these questions from time to time.

4. Use the Student Data Server and GLOBE Visualizations
In the Seasons chapter, your students will make use of the GLOBE Student Data Archive and GLOBE Visualizations. The maps, satellite images, visualizations, data base and data analysis tools are extremely powerful resources for your students to pursue their own investigations. The appendix has detailed instructions to help students access and use the data and tools called for in each activity.

Key Concepts and Skills in the Seasons Investigation

Concepts

- Seasonal changes demonstrate the interconnections among the Earth's systems.
- Environmental and climatic parameters follow predictable cycles over the course of a year;
- Environmental and climatic parameters respond to changing levels of insolation, with some responding more dramatically than others;
- Seasonal markers respond directly to the level of environmental and climatic parameters;
- Different regions experience seasons differently, and factors such as latitude, elevation, and geography impact local seasonal patterns.

Skills

- *Graphing* GLOBE data to show seasonal patterns.
- *Comparing* graphs and *analyzing* data.
- *Asking* questions and *developing* hypotheses.
- *Designing* and *implementing* investigations
- *Drawing* conclusions and *communicating* them to others.